© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719707

Harnessing Renewable Energy from Waste for Sustainable Rural Development in Niger State, Nigeria: Feasibility and Impact Assessment

AHMED JIBRIL WUSHISHI[1], MUHAMMAD AFUWAGI USMAN[2], YAU TANKO[3], ALHASSAN IBRAHIM MOHAMMED[4] & NDAJIYA TSADO IBRAHIM[5]

[1, 3, 5]Technical Drawing Department, USACOE, Minna, Niger State

[2, 4]Automobile Technology Department, Umaru Sanda Ahmadu College of Education, Minna. Niger State. Nigeria

Abstract- ***This study investigated the potential for harnessing renewable energy from agricultural and organic waste in Mariga and Katcha Local Government Areas (LGAs) of Niger State, Nigeria, for sustainable rural development. Given the region's abundant biomass generated by agricultural practices, rural communities grapple with significant energy access challenges, compounded by environmental degradation and reliance on traditional energy sources. The research also delves into biogas production and gasification technologies as effective methods for converting waste into clean energy solutions. The study involved one hundred and five (105) farmers, community leaders, and traders currently residing in the communities as respondents. The study used a structured questionnaire to collect data from the respondents; the results revealed that agricultural residues are highly abundant in the study areas, with respondents agreeing that waste is readily available and often poorly managed. A noteworthy significant difference in feasibility between Mariga and Katcha was found, with Mariga showing higher potential. However, the study made some recommendations, which among others include that government agencies and relevant stakeholders should organize regular training programs for rural dwellers, especially farmers, on the operation and maintenance of waste-to-energy technologies, and that the government and financial institutions should provide subsidies, grants, and low-interest loans to support the adoption of renewable energy technologies.***

Keywords: Renewable Energy, Waste Management, Sustainable Development, Biogas, Environmental Degradation, and Rural Energy Access.

I. INTRODUCTION

Niger is a state located in the North Central Geopolitical Zone of Nigeria, created in February, 1976 from the former North-Western State. Niger is the largest state by land mass in Nigeria and its name was derived from the River Niger, which flows through it and supports agricultural activities and fishing.

Agriculture is the main activity of the locals and the backbone of the state’s economy. The state's natural resources and fertile land make it one of Nigeria’s most economically significant states. Despite its important role in electricity generation through hydroelectric dams, the state still faces significant challenges in energy access, particularly in rural communities.

These challenges lead to environmental degradation, deforestation and air pollution (Gosai et al., 2026). The lack of a national grid further limits socio-economic activities and the living standards of the communities (Jegawa et al., 2025). As one of Nigeria’s major agricultural producers, the state generates large quantities of residues annually.

The large quantities of residues generated by farmers are mostly fed to animals, discarded or burned, thereby causing hazards to the environment (Güven & Yücel, 2025). These residues have the potential to generate a clean and sustainable renewable energy source.
Harnessing renewable energy can provide a clean and environmentally friendly energy alternative to the already available traditional energy sources in rural communities

Harnessing agricultural waste will reduce dependence on the unavailable national grid and boost economic activities through waste-harnessed processing, management and distribution (Kumar & Vyas, 2025).

Renewable energy from waste can also support the growth of local businesses, thereby stimulating economic growth in the communities (Samala & Bethi, 2025).

Though renewable energy technologies have been implemented in many communities in Nigeria, their use in these communities has been limited due to costs and lack of technical skills (Dinneya-Onuoha, 2025).

Besides, communities are often resistant to new energy technology, especially without awareness, funding, and training. To overcome these challenges, the research will suggest an approach that will include community participation, training, and technological support.

Renewable energy production also plays a significant role in combating environmental degradation and addressing climate change (Güven & Yücel, 2025).

Niger, like many other states, faces serious environmental challenges due to unsustainable land use, such as illegal mining and deforestation for firewood, leading to soil erosion and reduced agricultural productivity.

Biomass energy can replace firewood and reduce the pressure on forests, preserving Nigeria's biodiversity.

Furthermore, converting waste into renewable energy can reduce methane emissions from open burning, reducing greenhouse gases and contributing to global climate change mitigation efforts (Kumar & Vyas, 2025).

Adopting renewable energy in rural communities of Mariga and Katcha can improve the standard of living, boost economic activities, reduce reliance on firewood, and set an example for communities in other states.

The research investigated the feasibility of using residues for renewable energy in Niger State, assessing not only the types of residues available but also the technical and economic viability of various renewable energy conversion technologies.

The social, economic, and environmental benefits of this approach will be explored, while also acknowledging the challenges, such as a lack of infrastructure, technology, and technical expertise, that make it difficult to process waste into energy professionally (Ebisi, 2024).

This research will benefit Niger State and Nigeria at large in scaling up renewable energy adoption, creating sustainable renewable energy, and fostering economic, social, and environmental development in the communities.

II. RENEWABLE ENERGY FROM WASTE FOR SUSTAINABLE RURAL DEVELOPMENT

The shift to alternative energy has recently become important, particularly for future world stability and a friendly environment. The most important property of alternative energy sources is their environmental compatibility. In line with this characteristic, renewable energy sources like organic waste materials will become one of the most attractive substitutes in the near future (Oluwatayo, 2026).

Renewable energy from waste represents a practical and sustainable approach to addressing the persistent energy challenges faced by rural communities, particularly in developing countries like Nigeria (Olanrewaju-Elufowoju et al., 2026). All over the world, lots of Research and Development (R&D) is going on to solve local, regional and global energy problems.

Most of the researchers show their reliance on renewable energy technologies for sustainable development and for their daily energy needs through waste-to-energy routes (Seif et al., 2024), which do not cause negative societal impacts. Renewable energy supplies are of ever-increasing environmental and economic importance in all countries.

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719707

A wide range of renewable energy technologies are established commercially and recognised as growth industries by most governments. Renewable energy has a dual benefit of providing energy while also improving waste management practices (Bashiru et al., 2024). In many rural areas, improper disposal of agricultural residues leads to environmental problems such as air pollution, greenhouse gas emissions, and soil degradation (Juneja, 2024).

Converting these wastes into energy reduces open burning and minimizes methane emissions, thereby contributing to climate change mitigation and environmental protection (Ndubuisi & FNisafetyE, 2025). Furthermore, the use of biogas and other clean energy sources can significantly reduce deforestation caused by excessive dependence on firewood. From an economic perspective, waste-to-energy initiatives can stimulate rural development.

They can create employment opportunities in areas such as waste collection, processing, system installation, and maintenance. For farmers, who are the primary producers of agricultural waste, this presents an opportunity to diversify income sources and add value to what was previously considered a by-product (Jegawa et al., 2025). Additionally, access to reliable and affordable energy can enhance productivity by supporting Agro-processing activities, small businesses, and local enterprises.

Renewable energy from waste can also improve living standards in rural communities (Oladejo et al., 2025). The adoption of cleaner energy sources reduces indoor air pollution, which is a major cause of respiratory diseases, particularly among women and children who are most exposed during cooking (Bashiru et al., 2024).

Improved energy access also enhances educational outcomes by providing lighting for evening studies and supports better healthcare delivery in rural clinics. Despite these benefits, implementing waste-to-energy technologies in rural areas faces several challenges.

These include high initial investment costs, lack of technical expertise, limited awareness, and weak institutional support (Ndubuisi & FNisafetyE, 2025). Rural communities, especially farmers, may be willing to adopt such technologies but are often constrained by financial limitations and lack of access to training.

Therefore, for renewable energy from waste to achieve its full potential, targeted interventions are needed, including government subsidies, capacity-building programs, public awareness campaigns, and partnerships with the private sector.

In many rural areas, access to reliable electricity remains limited or entirely absent, forcing households to depend heavily on traditional energy sources such as firewood, charcoal, and kerosene (Oluwatayo, 2026). This reliance not only contributes to environmental degradation but also affects health, productivity, and overall quality of life.

Converting waste into renewable energy offers a viable alternative that simultaneously addresses energy poverty, waste management issues, and environmental sustainability (Bashiru et al., 2024).

Renewable waste materials from agriculture, industries and domestic sources are convertible to useful energy forms like biogas through waste-to-energy for sustainable growth of these communities that lack energy sources and are readily abundant in these rural communities due to the dominance of farming activities.

These materials, often considered useless or disposed of through open burning, can be transformed into valuable energy resources through technologies such as biogas production, biomass gasification, and anaerobic digestion (Ndubuisi & FNisafetyE, 2025).

Harnessing these locally available resources will enable rural communities to generate clean, affordable energy for cooking, lighting, and small-scale industrial activities.

Rural communities, particularly in Niger State, depend entirely on solid fuels such as wood, charcoal, and dung for their household energy needs.

The inability of these communities to utilize modern forms of energy limits opportunities for income generation and frustrates attempts to reduce poverty, and it also impacts the livelihoods of the communities. Furthermore, it contributes to global deforestation and climate change through both traditional greenhouse gas emissions and those from black and brown carbon (Majebi, 2026).

Expanding energy access for rural communities is a daunting task. Those without electricity, dependent on traditional fuels, tend to have income levels, purchasing power, and consumption levels far below what private companies and electric utilities typically deem profitable, reluctance further attenuated by the inaccessibility of these communities to national electricity grids (Eweka et al., 2022).

Public officials, like their private counterparts, prioritize investments in urban infrastructure where most of their constituents reside, and they often subsidize grid electricity to existing customers instead of expanding access to rural ones or incorporating off-grid technologies (Ndubuisi & FNisafetyE, 2025).

Renewable energy from waste offers a sustainable pathway for rural development by addressing energy shortages, improving environmental conditions, and creating economic opportunities (Majebi, 2026). Its success, however, depends on a holistic approach that integrates technology, policy support, community participation, and financial accessibility.

When effectively implemented, it can serve as a transformative tool for enhancing livelihoods and promoting sustainable development in rural communities. The study aims to provide policy recommendations to integrate renewable energy into remote communities, including suggestions for incentives, private-sector investment, and a sustainable energy production plan.

Furthermore, Training programs to develop community expertise in the professional and management aspects of the technology will be promoted.

The aim is to show that using residue to generate renewable energy is not only safe but also economically viable. By assessing residue management, socio-economic costs, and environmental benefits, this research provides a clear path to address energy shortages, economic underdevelopment, and environmental degradation in Niger State.

III. METHODOLOGY

The researchers used a quantitative research design to assess the availability and economic viability of waste and the environmental impacts of renewable energy technologies in Mariga and Katcha Local Government Areas (LGAs) of Niger State.

The respondents were local farmers, community leaders, and traders who use agricultural residues. Simple random sampling was used to select a sample of 105 respondents from the population of the communities.

The study aimed to assess the feasibility and impact of harnessing Renewable Energy from waste for sustainable rural development in Nigeria. The research instrument was a survey questionnaire with two sections. The first section makes an inquiry into respondents' demography, including local farmers, community leaders and traders.

The second section comprises 25 items that collect information on the availability and utilization of waste. The researchers used prior research as the foundation for developing the survey questionnaire. Then, experts validated the 5-point Likert scale administered to the respondents to assess its appropriateness.

Quantitative data were collected from the survey questionnaire, providing statistical insights into farmers' perceptions. The data discussed here centered on respondents' feedback regarding the availability of waste, its economic feasibility, environmental impact, policy and institutional factors, and the technical feasibility of waste-to-energy.

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719707

Besides descriptive statistics, the t-test was used for comparative analysis to determine whether there is a significant difference in feasibility between Mariga and Katcha.

IV. RESULT

The questionnaire was administered to 210 respondents, who were predominantly farmers in the local communities. Besides descriptive statistics, the t-test was used for comparative analysis to determine whether there is a significant difference in feasibility between Mariga and Katcha.

Likewise, to evaluate the data quantitatively and present it in a manageable form, descriptive statistics in the form of percentage responses were calculated to analyze respondents' feedback about their experience. All respondents (n = 210) completed the questionnaire, and their demographic information is presented.

As indicated in Table 1, among these respondents, 82.5% were local farmers, 15.6% were traders, and 8.6% were others.

Table 1. Respondent Demography

Measures	Features	Frequency	Percent
Gender	Male	187	89.0%
	Female	23	11.0%
	Total	210	100%
Age	51 years and above	39	18.6%
	41 – 50	51	24.3%
	31 – 40	57	27.1%
	20 - 30	63	30.0%
	Total	210	100%
Category	Farmers	183	87.1%
	Community Leaders	12	5.6%
	Traders	15	7.3%
	Total	210	100%

Table 1 shows that most respondents were farmers, indicating that the data reflects individuals directly involved in agricultural activities and waste generation.

Table 2. Respondents' Opinion on Waste Availability

Item	Mean	Std. Dev	Decision
Waste is abundant	3.85	0.92	Agree
Waste available year-round	3.40	1.01	Agree
Waste poorly utilized	4.10	0.88	Agree
Open burning is common	4.25	0.75	Strongly Agree
Waste can be better managed	4.30	0.70	Strongly Agree

Respondents generally agreed, with a mean of 3.85, that agricultural residues are abundant but poorly utilized, and that open burning is a common practice.

Table 3. Respondents' Opinion on Economic Feasibility

Item	Mean	Std. Dev	Decision
Technology is affordable	2.85	1.15	Disagree
Reduces energy cost	3.95	0.88	Agree
Creates jobs	4.15	0.80	Agree
Economically beneficial	4.05	0.85	Agree
Financial constraints exist	4.30	0.75	Strongly Agree

The result also shows that waste-to-energy is perceived as economically beneficial, with a mean = 4.05, but affordability remains a major barrier. In the other categories Social Acceptance (Mean = 3.91).

There is moderate willingness to adopt renewable energy, with awareness and training identified as key drivers. In Environmental Impact (Mean = 4.26), respondents strongly agree that waste-to-energy has significant environmental benefits.

But in the case of Policy and Institutional Factors (Mean = 3.67), there is a perceived lack of government support and infrastructure, highlighting the need for stronger policy intervention. While respondents believe conversion is possible, the lack of technical skills remains a major constraint as the mean technical feasibility of waste-to-energy remains (Mean = 3.56).

Table 4. Comparative Analysis (Mariga vs Katcha) t-test

LGA	N	Mean	Std. Deviation	Std. Error Mean
Mariga	52	3.92	0.78	0.113
Katcha	53	3.58	0.85	0.125

Note: There is a significant difference in feasibility between Mariga and Katcha ($p < 0.05$), with Mariga showing higher potential.

To determine whether there is a significant difference in the feasibility of renewable energy from waste between Mariga and Katcha LGAs, an independent samples t-test was carried out and it revealed a statistically significant difference in feasibility between Mariga ($M = 3.92$, $SD = 0.78$) and Katcha ($M = 3.58$, $SD = 0.85$), $t(92) = 2.08$, $p = 0.040$.

Since $p = 0.040 < 0.05$, there is a statistically significant difference between Mariga and Katcha. The difference is not due to chance because it is statistically significant. The higher feasibility observed in Mariga may be attributed to better availability of agricultural residues, higher awareness or exposure to renewable energy concepts and slightly better infrastructure or community readiness.

The lower mean score in Katcha suggests greater technical or institutional barriers and lower levels of awareness or acceptance.

V. DISCUSSION OF FINDINGS

The findings of this study provide important insights into the feasibility and impact of harnessing renewable energy from waste for sustainable rural development in Niger State, particularly in Mariga and Katcha LGAs.

The majority of the respondents in the dataset are farmers, indicating that the results are largely grounded in the experiences of those directly involved in agricultural production and waste generation.

This strengthens the validity of the findings, as farmers are the primary producers and users of agricultural residues. The study revealed that agricultural residues are highly abundant in the study areas, with respondents agreeing that waste is readily available and often poorly managed.

The dominance of farmers in the sample reinforces this finding, as they are directly responsible for generating crop residues and animal waste. The high level of agreement on practices such as open burning suggests that waste management remains largely inefficient and environmentally harmful.

This finding supports the argument that rural communities possess untapped biomass resources that can be converted into useful energy (Ebisi, 2024). However, the continued practice of open burning indicates a gap between resource availability and effective utilization.

The findings show that respondents generally believe that agricultural waste can be converted into energy, indicating awareness of the potential of renewable energy technologies. However, there was uncertainty regarding the ease of operation and a clear indication that communities lack the technical capacity to implement such systems.

Given that most respondents are farmers, this result highlights a critical issue: while farmers are resource-rich, they are often technology-poor. The agreement that a lack of technical skills is a barrier confirms that capacity building is essential for successful implementation.

Without adequate training and technical support, the feasibility of waste-to-energy projects may remain theoretical rather than practical, as asserted by (Imran et al., 2026).

The study found that although respondents acknowledge the economic benefits of waste-to-energy technologies, such as reduced energy costs and job creation, they generally perceive these technologies as unaffordable.

The large proportion of farmers in the sample provides context for this perception, as rural farmers typically have limited financial resources and access to credit facilities.

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719707

This suggests that economic feasibility is conditional rather than absolute. While the long-term benefits are recognized, the initial investment cost remains a major barrier. Therefore, Ebisi (2024) asserted that interventions such as subsidies, micro-financing, and cooperative ownership models may be necessary to enhance adoption.

The findings indicate a moderate to high level of willingness to adopt renewable energy technologies among respondents. in the case of social acceptance. However, cultural beliefs and a lack of awareness still influence acceptance levels.

Importantly, respondents strongly agreed that awareness campaigns and training would improve adoption. Since farmers make up most respondents, this suggests that adoption strategies must be community-centered and farmer- focused. Farmers are more likely to adopt innovations when they are practical, cost-effective, and supported by training.

This aligns with diffusion of innovation theory, which emphasizes the role of knowledge and social systems in technology adoption (Al-Awamleh et al., 2026). The study also shows strong agreement that converting waste into renewable energy can reduce deforestation, air pollution, and reliance on firewood. This is significant in rural areas where farmers depend heavily on biomass for cooking and energy.

The responses from farmers provide practical validation of these environmental benefits, as they directly experience the negative effects of deforestation and land degradation. The findings therefore support the argument that waste-to-energy technologies can serve as a dual solution, addressing both energy shortages and environmental challenges (Gosai et al., 2026).

The results reveal a perceived lack of government support and inadequate infrastructure for renewable energy development. At the same time, respondents emphasized the importance of private sector involvement and community participation. Given that most respondents are farmers operating in rural settings, this indicates the disconnect between policy frameworks and grassroots realities. Farmers often have limited access to government programs, and this may explain their perception of weak institutional support. Strengthening policy implementation at the local community level is therefore crucial, as asserted by (Jegawa et al., 2025).

The findings, therefore, indicate that resource availability is not the problem, as waste is abundant; capacity and affordability are the real constraints. This means that any successful waste-to-energy initiative must target farmers directly, provide technical training, ensure financial accessibility and promote community participation.

The study demonstrates that harnessing renewable energy from waste is both feasible and beneficial for rural development in Niger State. However, its success depends on addressing key barriers related to technical skills, affordability, and institutional support.

The strong representation of farmers in the study underscores the importance of designing interventions that are practical, inclusive, and tailored to rural agricultural communities.

VI. CONCLUSION

This study highlights the significant potential of harnessing renewable energy from agricultural and organic waste in Mariga and Katcha LGAsNiger State as a sustainable solution to rural communities' energy access challenges.

By effectively utilizing biomass residues, the region can transform waste into clean energy, thereby addressing critical issues such as air pollution, environmental degradation, and reliance on conventional energy sources.

The study emphasizes that community participation, training, and technological support are essential for fostering acceptance and successful implementation of renewable energy technologies. The dual benefits of improving living standards and stimulating economic opportunities through job creation in waste management further support the case for renewable energy adoption.

While barriers such as infrastructure deficits and resistance to new technologies persist, proactive measures can help communities overcome these challenges.

The shift towards renewable energy not only plays a crucial role in enhancing the socio-economic conditions of Niger State but also contributes to broader climate change mitigation efforts, demonstrating that sustainable rural development is both feasible and impactful.

VII. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:
Government agencies and relevant stakeholders should organize regular training programs for rural dwellers, especially farmers, on the operation and maintenance of waste-to-energy technologies such as biogas systems. This will address the identified technical skills gap and enhance local capacity for sustainable implementation.

The government and financial institutions should provide subsidies, grants, and low-interest loans to support the adoption of renewable energy technologies. Community-based financing models such as cooperatives should also be encouraged to enable farmers to pool resources and invest collectively.

The government should develop and implement clear policies and regulatory frameworks that support renewable energy development in rural areas. This includes providing incentives for private sector investment, ensuring rural inclusion in national energy plans, and strengthening institutional coordination.

Renewable energy projects should adopt a community-driven approach, involving local stakeholders in planning, implementation, and management. This will enhance ownership, sustainability, and acceptance of the projects.
Efforts should be made to improve rural infrastructure, including access roads, energy distribution systems, and technical service centers, to support the successful deployment of renewable energy technologies.

REFERENCES

[1] Al-Awamleh, H. K., Omoush, M. M., Ahmed, R. T., Assaf, N., Alqudah, M. Z., & Samara, H. (2026). Innovation in energy management: Mapping knowledge development and technological change. International Journal of Energy Sector Management, 20(3), 734-758.

[2] Bashiru, O., Ochem, C., Enyejo, L. A., Manuel, H. N. N., & Adeoye, T. O. (2024). The crucial role of renewable energy in achieving the sustainable development goals for cleaner energy. Global Journal of Engineering and Technology Advances, 19(3), 011-036.

[3] Dinneya-Onuoha, E. (2025). Unlocking renewable energy materials in Nigeria: availability, application, and roadmap for sustainability. RSC Sustainability, 3(6), 2534-2566.

[4] Ebisi, C. M. (2024). Biomass resources and energy access in Nigeria: a scoping review. Nat. Gas, 378, 25.

[5] Eweka, E. E., Lopez-Arroyo, E., Medupin, C. O., Oladipo, A., & Campos, L. C. (2022). Energy landscape and renewable energy resources in Nigeria: A review. energies, 15(15), 5514.

[6] Gosai, H. G., Sharma, A., & Patel, J. (2026). Energy efficiency and renewable energy integration waste management strategies for smart cities. In Future Smart Cities (pp. 259-288). Elsevier.

[7] Güven, A. F., & Yücel, E. (2025). Sustainable energy integration and optimization in microgrids: enhancing efficiency with electric vehicle charging solutions. Electrical Engineering, 107(2), 1541-1573.

[8] Imran, M., Yin, X., Khan, M. K., Wahab, S., & Jijian, Z. (2026). Revitalizing waste: unraveling circular dynamics in EU waste-to-energy-insights into incineration, technology, and primary energy supply. Financial Innovation, 12(1), 100.

[9] Jegawa, M., Mohammed, M., Muhammad, A., Sani, J., & Agboola, B. (2025). Transforming Biomass into Energy: A Pathway to Sustainable Energy Security in Northern Nigeria. Journal of Science and Technology, 30(6).

[10] Juneja, P. (2024). Biomass waste conversion technologies for its utilization and energy generation in India: a perspective. IOP Conference Series: Earth and Environmental Science,

[11] Kumar, J., & Vyas, S. (2025). Comprehensive review of biomass utilization and gasification for sustainable energy production. Environment, Development and Sustainability, 27(3), 1-40.

[12] Majebi, S. (2026). Sustainability Assessment of Biomass Utilisation for Distributed Energy Systems in Nigeria City St George's, University of London].

[13] Ndubuisi, O. G., & FNisafetyE, F. (2025). Impact of Advanced Renewable Energy Technologies and their Integral Role in Achieving Sustainability.

[14] Oladejo, O. M., Shava, E., & Muringa, T. P. (2025). The feasibility of implementing renewable energy systems by local municipalities for households and economic entities. Frontiers in Energy Research, 13, 1517054.

[15] Olanrewaju-Elufowoju, O. K., Omoniyi, O., & Banigo, T. R. (2026). Renewable Energy Transition In Sub-Saharan Africa: Legal Prospects, Challenges And Strategic Pathways For Nigeria. Sustainable Development, Law and Policy, 17(1), 677-714.

[16] Oluwatayo, I. B. (2026). Energy Poverty in Sub-Saharan African Countries: Harnessing Green Energy for Youth Employability and Economic Transformation. International Journal of Energy Economics and Policy, 16(2), 626.

[17] Samala, N., & Bethi, C. (2025). Harnessing synergy: a holistic review of hybrid renewable energy systems and unified power quality conditioner integration. Journal of Electrical Systems and Information Technology, 12(1), 4.

[18] Seif, R., Salem, F. Z., & Allam, N. K. (2024). E-waste recycled materials as efficient catalysts for renewable energy technologies and better environmental sustainability: R. Seif et al. Environment, Development and Sustainability, 26(3), 5473-5508.